This document serves as an addendum to the original report:

Oregon Nearshore Semi-Pelagic Rockfish Survey

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Goal:
The goals of this addendum are to update the population estimates for Black Rockfish (*Sebastes melanops*) using an updated target strength and length relationship and highlight topics for the upcoming Oregon Black Rockfish STAT briefing on January 11th, 2023. Updates resulting from the STAT team discussion are also included.

In the original report, echo integration of backscattering cross-section data was calculated using the standard target strength to length equation given as:

$$TS=20\log_{10}(L)-b_{20}$$

Equation 1

where TS is the fish target strength, L is the fish length in cm, and b_{20} is a species-specific constant. Specifically, we used:

$$TS_{38\ kHz}=20\log_{10}(L)-67.7$$

Equation 2

$$TS_{201\ kHz}=20\log_{10}(L)-71.9$$

Equation 3

where the b_{20} constant for the 38 kHz transducer (Equation 2) came from Hwang (2015) and the 201 kHz transducer (Equation 3) came from Rasmuson et al. (2021)."

However, after discussion with the SSC review panel and most importantly our CIE reviewer, it was suggested that b_{20} values from multiple published studies be averaged and used for echo integration of the 38 kHz transducer (Table 1).

Table 1: Published b_{20} values averaged for use in echo integration.

Publication	**b_{20}**
Hwang 2015	-69.01
Gauthier and Rose 2002	-68.7
Gauthier and Rose 2001	-68.1
Kang and Hwang 2003	-67.7
Average	-68.38 ± 0.58

Implementation:
Using the corrected target strength and length relationship for 38 kHz data we calculated the abundance of Black Rockfish for the pass 1 data. As a reminder, abundances were calculated

separately for the above near bottom exclusion zone, within near bottom exclusion zone and background zone (Figure 1).

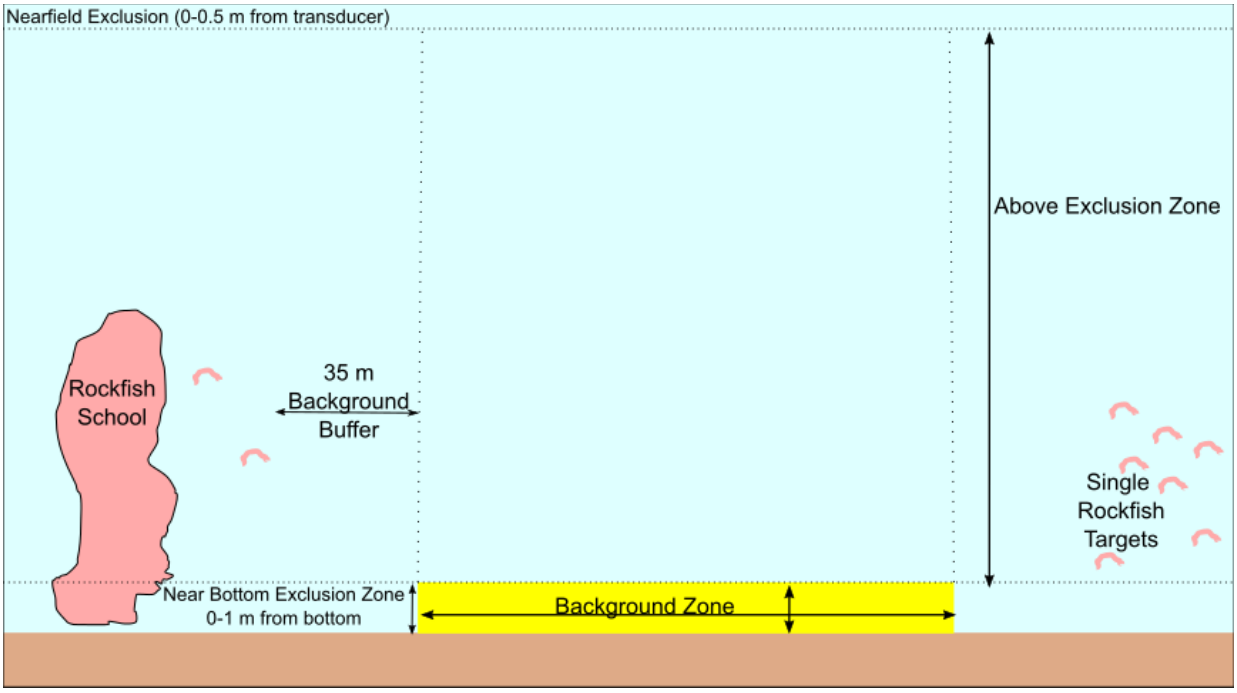

Figure 1. Diagram of different analytical zones used in the ODFW nearshore semi-pelagic rockfish survey.

It is worth noting that updating the b_{20} value only affected the abundance estimates for the above and within exclusion zone data. Use of a smaller b_{20} value resulted in a decreased abundance value for Black Rockfish (Table 2).

Considerations Discussions for 1/11/2023:

1. Because an average of b_{20} values was used, there is associated uncertainty with the average. At the suggestion of the SSC this uncertainty is not included in the estimate but rather should be incorporated after the estimate is generated. This method needs to be developed.
2. No *in situ* calibration of the transducers was achieved during the survey. Attempts were made but the sea state in Oregon ultimately makes this challenging (something experienced by the NMFS Pacific Whiting survey as well).
3. Due to wide-spread hypoxia experienced in the northern half of the survey during pass 1, an additional pass from Three Arch Rocks to Waldport (pass 2) was completed. The inclusion of pass 2 data in the design-based estimate was not supported by SSC, therefore design-based population estimates from pass 1 only were included in this addendum.
4. A model-based population estimate was completed for both passes and included in the original report. The use of the model-based approach was not supported by SSC and therefore not included in this addendum.
5. We combined the standard deviations from each zone (above exclusion, within exclusion and background) using Equation 5 below (EQ2 in the SSC report):

$$Var(X+Y+Z) = Var(X) + Var(Y) + 2Cov(X,Y) + Var(Z)$$

(SSC EQ 1) Equation 4

$$Var(X+Y+Z) = Var(X) + Var(Y) + 2\sqrt{Var(X) * Var(Y)} + Var(Z)$$

(SSC EQ 2) Equation 5

Per the recommendations of the SSC, we initially used Equation 4 (EQ1 in the SSC Report), but then were told to use Equation 5. A discussion of this is probably a good idea.

References:

Gauthier, S, and G A Rose. "*In Situ* Target Strength Studies on Atlantic Redfish (*Sebastes* Spp.)." *ICES Journal of Marine Science* 59, no. 4 (August 2002): 805–15. https://doi.org/10.1006/jmsc.2002.1248.

Gauthier, S and G A Rose. "Target Strength of Encaged Atlantic Redfish (*Sebastes* Spp.)." *ICES Journal of Marine Science* 58, no. 3 (June 2001): 562–68. https://doi.org/10.1006/jmsc.2001.1066.

Hwang, B. "Morphological Properties and Target Strength Characteristics for dark banded rockfish (*Sebastes inermis*)." *Journal of the Korean Society of Fisheries Technology* 51, no. 1 (February 28, 2015): 120–27. https://doi.org/10.3796/KSFT.2015.51.1.120.

Kang, D, and D Hwang. "*Ex Situ* Target Strength of Rockfish (*Sebastes schlegeli*) and Red Sea Bream (*Pagrus major*) in the Northwest Pacific." *ICES Journal of Marine Science* 60, no. 3: 538–43. https://doi.org/10.1016/S1054-3139(03)00040-7.

Rasmuson LK, Fields SA, Blume MTO, Lawrence KA, Rankin PS (2021) Combined video–hydroacoustic survey of nearshore semi-pelagic rockfish in untrawlable habitats. ICES J Mar Sci 79, no. 1: 100-116 https://doi.org/10.1093/icesjms/fsab245

Notes from January 11th, 2023 Discussion

- Add addenda with complete derivation of all population estimate equations
- Calculate population estimates using each of the four b_{20} values proposed in the literature instead of a single population estimate with an averaged b_{20}.

Notes from February 13th, 2023 Discussion

- Based on review of the tables of b20 values (available in "B20 Analysis Addenda.xlsx") the averaged b20 value (Table 1) was applied and accepted for generating population estimates (Table 2).

Equations Addenda

Above Exclusion Zone

Average echo integration density and standard deviation was calculated as:

$$\overline{EIdens\_above_{h,r}} = \frac{\sum_i EIdens\_above_{t,h,r}}{T_{h,r}}$$

Equation 6

$$EIvar\_above_{h,r} = \frac{\sum\left(EIdens\_above_{t,h,r} - \overline{EIdens\_above_{h,r}}\right)^2}{T_{h,r} - 1}$$

Equation 7

$$EIstdev\_above_{h,r} = \sqrt{EIvar\_above_{h,r}}$$

Equation 8

Where $\overline{EIdens\_above_{h,r}}$ is the average echo integration density (density from schools) in number of fish per m^2 for each habitat type (h) in region (r) at transect (t). T is the total number of transects at habitat type (h) in region (r). $EIvar\_above_{h,r}$ is the variance of the average echo integration density for each habitat type. $EIstdev\_above_{h,r}$ is the standard deviation of average echo integration density for each habitat group in each region. These averages were calculated for each region independently and for the state as a whole.

Average echo counting density and standard deviation was calculated as:

$$\overline{ECdens\_above_{h,r}} = \frac{\sum_i ECdens\_above_{t,h,r}}{T_{h,r}}$$

Equation 9

$$ECvar\_above_{h,r} = \frac{\sum\left(ECdens\_above_{h,r} - \overline{ECdens\_above_{h,r}}\right)^2}{T_{h,r} - 1}$$

Equation 10

$$ECstdev\_above_{h,r} = \sqrt{ECvar\_above_{h,r}}$$

Equation 11

Where $\overline{ECdens_{h,r}}$ is the average echo counting density in number of fish per m^2 for each habitat type (h) in region (r) at transect (t). T is the total number of transects at habitat type (h) in region (r). $ECvar\_above_{h,r}$ is the variance of the echo counting density at habitat type (h) in region (r) and transect (t). $ECstdev\_above_{h,r}$ is the standard deviation of echo counting density at habitat type (h) in region (r).

Echo counting (EC) and echo integration (EI) densities were turned into regional abundances by multiplying each density (EC and EI) by the total area (m^2) of each region. Where A is the area of habitat (h) in region (r).

$$EIabund\_above_{h,r} = \overline{EIdens\_above_{h,r}} * A_{h,r}$$

Equation 12

$$EIabund\_stdev\_above_{h,r} = EIstdev\_above_{h,r} * A_{h,r}$$

Equation 13

$$ECabund\_above_{h,r} = \overline{ECdens\_above_{h,r}} * A_{h,r}$$

Equation 14

$$ECabund\_stdev\_above_{h,r} = ECstdev\_above_{h,r} * A_{h,r}$$

Equation 15

Abundances were calculated for the north, central, south, and statewide regions as well as a statewide-combined summation which summed the values from the north, central and southern regions. Abundance values from echo integration and echo counting for each region were aggregated by summing the abundances (Equation 11). Standard deviation of the aggregation was calculated as:

$$Above\_Abund_r = \sum_h EIabund\_above_{h,r} + \sum_h ECabund\_above_{h,r}$$

Equation 16

$$Above\_AbundSD_r = \sqrt{\sum_h EIabund\_stdev\_above_{h,r}{}^2 + \sum_h ECabund\_stdev\_above_{h,r}{}^2}$$

Equation 17

Within Exclusion Zone

Average echo integration density and standard deviation was calculated as:

$$\overline{EIdens\_within_{h,r}} = \frac{\sum_i EIdens\_within_{t,h,r}}{T_{h,r}}$$

Equation 18

$$EIvar\_within_{h,r} = \frac{\sum\left(EIdens\_within_{t,h,r} - \overline{EIdens\_within_{h,r}}\right)^2}{T_{h,r} - 1}$$

Equation 19

$$EIstdev\_within_{h,r} = \sqrt{EIvar\_within_{h,r}}$$

Equation 20

Where $\overline{EIdens\_within_{h,r}}$ is the average echo integration density (density from schools) in number of fish per m^2 for each habitat type (*h*) in region (*r*) at transect (*t*). *T* is the total number of transects at habitat type (*h*) in region (*r*). $EIvar\_within_{h,r}$ is the variance of the average echo integration density for each habitat type where (*t*) is the total number of transects at habitat type (*h*) in region (*r*). $EIstdev\_within_{h,r}$ is the standard deviation of average echo integration density for each habitat group in each region. These averages were calculated for each region independently and for the state as a whole. Where A is the area of habitat (*h*) in region (*r*).
Within exclusion zone EI densities were turned into regional abundances by multiplying EI density by the total survey area (m^2) of each region. Echo counting does not occur within the exclusion zone.

$$EIabund\_within_{h,r} = \overline{EIdens\_within_{h,r}} * A_{h,r}$$

Equation 21

$$EIabund\_stdev\_within_{h,r} = EIstdev\_within_{h,r} * A_{h,r}$$

Equation 22

Abundances were calculated for the north, central, south, and statewide regions as well as a statewide-combined summation which summed the values from the north, central and southern regions.

$$Within\_Abund_r = \sum_h EIabund\_within_{h,r}$$

Equation 23

$$Within\_AbundSD_r = \sqrt{\sum_h EI\_abund\_stdev\_within_{h,r}{}^2}$$

Equation 24

Background Density and Abundance

We used fish counts from the BASSCam's downward-facing camera to generate an areal density of each species/species group within the exclusion zone that are not associated with acoustic data (fish schools or single targets). Drops within 35 m of a fish school or single targets were excluded. We then used the counts from the drops conducted at distances > 35 m to derive a density of fish. To do so, we calculated the amount of seafloor observed by the downward-facing camera on each drop, based on camera field of view and height off bottom, then divided by the number of fish we counted. The density was calculated for each species/species group, and we refer to it as the background density.

$$\overline{BackDens_{h,r}} = \left(\sum \frac{Nfish_{d,h,r}}{DownArea_{d,h,r}}\right) * \left(\frac{1}{D_{h,r}}\right)$$

Equation 25

$$Backvar_{h,r} = \frac{\sum\left(BackDens_{d,h,r} - \overline{BackDens_{h,r}}\right)^2}{D_{h,r} - 1}$$

Equation 26

$$Back\_stdev_{h,r} = \sqrt{Backvar_{h,r}}$$

Equation 27

$$BackAbund_{h,r} = \overline{BackDens_{h,r}} * A_{h,r}$$

Equation 28

$$BackAbund_r = \sum_h BackAbund_{h,r}$$

Equation 29

Where $Nfish_{d,h,r}$ is the number of observed on drop *(d)* in habitat *(h)* and region *(r)* and $DownArea_{d,h,r}$ is the area viewed by the down camera on drop *(d)* in habitat *(h)* and region *(r)*. $BackAbund_{h,r}$ is the abundance of fish in the background in habitat *(h)* and region *(r)*. *D* is the total number of drops at habitat type (*h*) in region (*r*).

Combining Estimates - SSC Approach

To combine the estimate using the SSCs implementation of the Cauchy Schwarz Inequality we did:

$$Abundance_r = BackAbund_r + Above\_Abund_r + Within\_Abund_r$$

Equation 30

$$VarAbund_r = Above\_AbundSD_r{}^2 + Within\_AbundSD_r{}^2 + 2\sqrt{\left(Above\_AbundSD_r{}^2 + Within\_AbundSD_r{}^2\right)} + Back\_stdev_{h,r}$$

Equation 31

Combining Calculating Covariance Matrix

To calculate the actual covariance matrix, rather than using the inequality theorem, we calculated covariance of the raw transect densities calculated in Equation 6 and Equation 21. However, combining covariance of data from these two sources creates an issue because “above exclusion zone” data (Equation 6) includes single targets but “within exclusion zone” data (Equation 21) does not.

Table 2. Updated population estimates for Black Rockfish for pass 1. Number of fish is reported in number of individuals, and biomass is in metric tons. Standard deviations of Combined Zones were combined assuming the above exclusion and within exclusion data are correlated and applied using the Cauchy Schwarz Inequality equation approved by the SSC.

		North	Central	South	Statewide-Combined	Statewide
Number of Fish ± SD	Above Exclusion	2,888,366 ± 1803396	324 ± 145	7,318,965 ± 5,205,662	10,207,655 ± 5,509,188	10,161,131 ± 6,873,895
	Within Exclusion	406,182 ± 314917	43 ± 33	2,015,793 ± 2,102,857	2,422,018 ± 2,126,307	2,063,645 ± 2,241,429
	Background	101,183 ± 126249	713 ± 901	263,890 ± 334,689	365,786 ± 357,710	365,786 ± 461,810
	Combined Zones	3,395,731 ± 2,122,072	1,080 ± 918	9,598,648 ± 7,316,178	12,995,459 ± 7,643,869	12,590,562 ± 9,127,015
Biomass of Fish ± SD	Above Exclusion	2,899.51 ± 1,810.35	0.33 ± 0.15	7,347.19 ± 5,225.74	10,247.03 ± 5,530.44	10,200.32 ± 6,900.41
	Within Exclusion	407.75 ± 316.13	0.04 ± 0.03	2,023.57 ± 2,110.97	2,431.36 ± 2,134.51	2,071.6 ± 2,250.07
	Background	101.57 ± 126.74	0.72 ± 0.9	264.91 ± 335.98	367.2 ± 359.09	367.2 ± 463.59
	Combined Zones	3,408.83 ± 2,130.25	1.09 ± 0.92	9,635.67 ± 7,344.4	13,045.59 ± 7,673.36	12,639.12 ± 9,162.22
CV	Above Exclusion	62.44	44.72	71.13	53.97	67.65
	Within Exclusion	77.53	77.46	104.32	87.79	108.62
	Background	124.77	126.41	126.83	97.79	126.25
	Combined Zones	62.49	84.20	76.22	58.82	72.49

Excerpt from the report explaining the values in Table 2:

“Abundances were calculated for the north, central, south, and statewide regions as well as a statewide-combined summation which summed the values from the north, central and southern regions. Statewide abundance was calculated from average statewide density and total habitat area for the survey area. These summations were applied to the data above the exclusion zone and within the exclusion zone, though there was no echo counting within the exclusion zone, only echo integration.

Biomass was calculated by multiplying the estimated abundance for each region (including the statewide-combined) by the proportion of fish in each size class (1 cm bins) for each species group. The number in each size class was converted to weight using the length weight relationships obtained from the hook and line data.”